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Validity and Reliability of Self-Perception-Based Submaximal Fitness Tests in Young Adult Females: An Educational Perspective

Pietro Luigi Invernizzi [1], Gabriele Signorini [1], Andrea Bosio [2], Gaetano Raiola [3] and Raffaele Scurati [1,*]

1 Department of Biomedical Sciences for Health, Università degli Studi di Milano, 20129 Milan, Italy; pietro.invernizzi1@unimi.it (P.L.I.); gabriele.signorini@unimi.it (G.S.)
2 Human Performance Laboratory, Mapei Sport, 21057 Olgiate Olona (VA), Italy; andrea.bosio@mapeisport.it
3 Department of Human, Philosophical and Education Sciences, University of Salerno, 84084 Fisciano (SA), Italy; graiola@unisa.it
* Correspondence: Raffaele.scurati@unimi.it

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Abstract: Background: In physical activity, testing procedures generally require maximal efforts. They are not always administrable or appropriate (e.g., with beginners, elderly, or in school); therefore, alternative submaximal procedures might be more fitting. This study aimed to assess the criterion validity and reliability of submaximal tests based on perceptual variables to be used instead of the corresponding maximal procedures to evaluate muscular endurance, flexibility, and cardiorespiratory fitness. The sustainability of this "educational" rationale to achieve the individual self-government and self-determination of testing and exercising has been further discussed. Methods: A total of 16 female gym practitioners (age 23 ± 3 years) performed five submaximal tests (push-up, S-PU; crunch, S-CR; wall-sit, S-WS; bending forward, S-BF; Step test, S-ST), whose results were compared to those from the corresponding maximal tests (push-up, PU; crunch, CR; wall-sit, WS; sit-and-reach, S&R; Yo-yo, YY). Results: The Interclass Correlation Coefficient (ICC) was higher than 0.8 in all of the submaximal tests. High correlations were found between all submaximal and maximal tests except between YY and S-ST, though their mean heart rates were correlated. Conclusions: Submaximal tests based on an internal load at about 50% of the maximal perceived exertion are equally valid and reliable to the corresponding gold-standard maximal tests, except for the cardiorespiratory evaluation. The educational rationale of this study supports self-acting as a calibration mechanism of physical activity, promoting a proper use of the body but not its overuse.

Keywords: perceived exertion; physical literacy; assessment; muscular endurance; flexibility; cardiorespiratory fitness; physical education

1. Introduction

Physical inactivity has been strongly associated with the epidemic emergence of chronic diseases [1]. Benefits from regular physical activity in humans have been extensively documented in the literature. Programs of regular exercise, including cardiorespiratory, resistance, flexibility, and neuromotor exercise training, in addition to activities of daily living were shown to be fundamental to improving and maintaining physical fitness and health in adults [2–4]. According to the Physical Activity Guidelines for Americans, at least 150 min per week of moderate-intensity physical activity, 75 min per week of vigorous-intensity physical activity, or a combination of moderate and vigorous physical activity are recommended for adults [5]. In addition, in healthy adults, flexibility is crucial for maintaining the necessary range of joint movements. Consequently, flexibility exercises for each major group (60 s per exercise) are recommended twice a week or more [2].

1.1. Good Health Practices: A Precious Good to Properly Manage

Although most of the literature has indicated the procedures and the amount of activity that should be prescribed, less attention has been paid to the comfort, the safety, and the pleasantness perceived by performers during the physical exercise [6]. This may allow the best functional use of the body and avoid any sort of abuse of it, and sets the proper psychophysical work to adapt it to any situation (beginners, school, elderly, diseased, etc.). This concept is part of physical literacy (PL), which has highlighted that body perception and self-awareness are the main features of the education of movement and through movement [7].

Embodied cognition and enaction concepts further support the idea of an interaction between the mind and the body, based on an integrated system composed of the living organism, the sensorimotor dynamics, and the environment [8]. The living organism considers individual features and potentials; the sensorimotor dynamics contemplate the learning of the ability to perceive and comprehend the effects of movements on the organism; the environment contributes to the conceptualization of adjustment and transfer of the practice coming from self-consciousness, needs, and adaptation requirements. This system strengthens the relevance of features, such as perception and awareness for physical activity administration, and promotes the unity of the human being in actions.

1.2. From the “Drug-Like” to the “Educational” Rationale of Physical Activity

The “drug-like” rationale is based on the idea that physical exercise acts as a drug to make and maintain human health and fitness, considering the human being as a mechanical system to perform exercise and to be trained [9]. The “educational” rationale promotes physical activity as a way to educate and develop all of the components of the human being [10]. As in the previous rationale, health and fitness are also expected as a result, but, differently, the issues of PL also support the idea of the unity and the complexity of the human being [11]. This extends the mainly physically based “drug-like” approach rationale for physical activity: Individuals have to be physically healthy but proficient in managing one’s perception, mind, and emotions, and in coping with the different contexts that occur [12]. Therefore, even if both rationales aim at health and fitness, they result rather differently. The “drug-like” rationale emphasizes the objective and the quantitative features of physical exercise, whereas the “educational” rationale is addressed to enhance the importance of the subjective and qualitative features (awareness, perception, interpretation, emotions, motivation) associated with the objectivity. This educational approach, included in the previously highlighted concept of PL, is addressed to promote the self-government and self-determination in order to better direct the development of the human being and society [13].

In the literature, the educational-judo approach by Jigoro Kano, as well as Hebertism, has already been applied in this model towards a utility and social emancipation [14,15]. From the perspective of a shift of paradigm [16] from an exclusively “drug-like” rationale to the “educational” rationale, the present study considers physical exercise as a diagnostic instrument.

1.3. Diagnostics and Good Health Practices: “Drug-Like” or “Educational” Rationale?

In the “drug-like” perspective, the assessment of cardiovascular fitness, muscular fitness, and flexibility can be done by specific tests usually based on maximal efforts, requiring a maximal exertion and, as a consequence, a very high level of motivation [17]. Therefore, when administration of maximal tests is not suitable because of their undesirable effects on motivation, possibly inducing exercise interruption or inappropriate measurements and evaluation, alternative procedures are required for fitness assessment. For this purpose, several studies have considered the use of submaximal tests based on external load [18,19]. Unfortunately, submaximal tests also cannot be used when risk factors emerge or are even just suspected [3].

From the "educational" perspective, a few studies have examined the validity of submaximal tests based on perception of effort to assess individuals involved in fitness training programs [20–22]. In particular, a study by Crotti et al. [23] involving moderately and well-trained male runners found correlations between some maximal tests for assessment of cardiovascular and muscular fitness and the corresponding submaximal forms of the same tests based on the achievement of a given rating of perceived exertion (i.e., a level corresponding to 5 on the Borg CR-10 scale).

From the perspective of the "educational" rationale, we intended to validate a battery of submaximal field-based fitness tests in young adult female participants (who practiced moderate physical activity in their spare time and not in competition) that used perceptual variables, such as the rate of perceived exertion and the intensity of the stretch, to evaluate the muscular endurance, the flexibility, and the cardiorespiratory fitness of the participants.

This study supports the sustainability of the "educational" rationale for achieving individual self-government and self-determination. These two traits, mediated by the perception of effort and pain, contribute to an ecological self-management of the physical activity performed by an individual during their entire lifespan [7]. Furthermore, the application of this rationale makes physical activity and movement in general a powerful tool for forming a human being, and not just merely educating to movement (reductive vision).

The aim of the present study, which can be considered a follow-up to the study by Crotti et al. [23], was to investigate the relationships between maximal and submaximal tests in active young adult female participants, when self-acting is used as a calibration mechanism to manage physical activity and testing procedures.

2. Materials and Methods

2.1. Participants

Sixteen female gym practitioners volunteered to participate in this study (age 23 ± 3 years, body mass 53.6 ± 6.9 kg, height 1.63 ± 0.05 m, BMI 20.0 ± 2.1 kg·m^{-2}). The physical activity of the participants was measured by the International Physical Activity Questionnaire (IPAQ) [24] and resulted to be of moderate intensity (2098 ± 1550 METs—min per week; Walking = 5.1 ± 1.4 days per week, 48.4 ± 59.5 min per day; Moderate = 1.3 ± 1.1 days per week, 36.9 ± 33.2 min per day; Vigorous = 1.8 ± 1.8 days per week, 52.5 ± 34.4 min per day). The participants were invited to maintain their physical activity habits during the entire study period.

All of the participants received a detailed explanation of the procedures and possible risks, then they signed an informed consent form. They were informed they could interrupt their participation in the study at any time. The study was conducted in accordance with the declaration of Helsinki and was approved by the local University Ethics Committee.

2.2. Experimental Design

During the first session, the investigators explained the testing procedures selected to assess the muscular endurance, the flexibility, and the cardiorespiratory fitness in both the maximal and submaximal forms (Table 1). The IPAQ questionnaire was also administered; then, participants were familiarized with the exercises composing the submaximal testing sequence and the way to stop the exercise based on the rate of the perceived exertion (for further details, see 2.4. Measurements of the Submaximal Tests). Due to the importance of individual self-perception in improving the accuracy of the submaximal testing procedure, the participants were encouraged to cooperate with reciprocal observations and to actively talk about their perceptions (720 min over three weeks). These cooperative and collaborative methods [25–28] allowed the solving of any doubt, fault, or incertitude while using the perceived exertion scales as a tool to stop exercising.

Table 1. Tests selected to assess muscular endurance, flexibility, and cardiorespiratory fitness. Maximal tests and their corresponding submaximal procedures.

	Maximal Test	**Submaximal Test**
Muscular endurance	Push-up test (PU)	Submaximal push-up test (S-PU)
	Crunch test (CR)	Submaximal crunch test (S-CR)
	Wall-sit test (WS)	Submaximal wall-sit test (S-WS)
Flexibility	YMCA sit-and-reach test (S&R)	Submaximal bending forward of the trunk test (S-BF)
Cardiorespiratory fitness	Yo-yo IRL1 test (YY)	Submaximal step test (S-ST)

To assess the reliability of the submaximal tests, the testing protocol was repeated three times, once a week over three consecutive weeks (Figure 1). A fourth week served to administer the maximal tests. Familiarization with the maximal tests occurred at the end of the third week. They were administered over two consecutive days to reduce the effect of fatigue, leaving the Yo-yo Intermittent Recovery Test Level 1 (IRL1) for the last day.

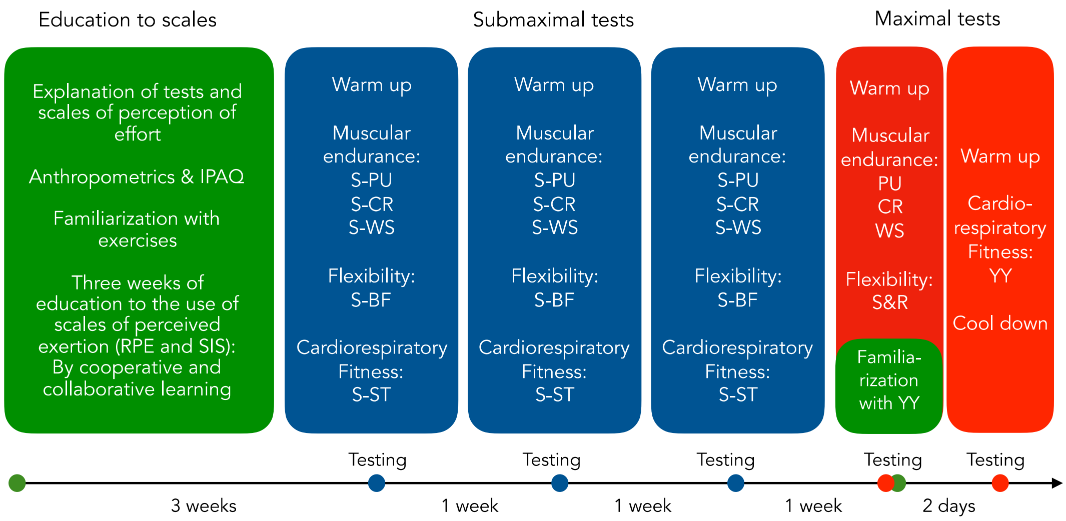

Figure 1. Timeline of the testing procedure.

2.3. *Measurements (Maximal Tests)*

Five validated fitness tests were chosen as a reference to evaluate the muscular strength, flexibility and cardiorespiratory fitness of the participants.

2.3.1. Muscular Endurance

Push-up test (PU): The PU measures the muscular endurance of the upper limbs. The performer starts from the prone position, with the hands under the shoulders and the fingertips pointing forward. She has to push her body up by extending the arms, with the back straight, the head up, and the knees used as a support point. Afterwards, the performer has to return to the starting position until the chin reaches the floor [3]. The number of consecutive push-ups performed without any rest is recorded.

Crunch test (CR): The CR measures the endurance of the abdominal muscles. The performer starts from the supine position and has to flex the trunk, sliding the hands forward without lifting them off the ground [3]. During the test, she has to keep a specific pace, set at 40 bpm by a metronome: At the first beep, the curl-up begins, the highest position is reached at the second beep, and the starting position is reached at the third beep. One repetition is counted at each return to the starting position. The test ends either when the performer completes 75 curl-ups or when the pace is broken.

Wall-sit test (WS): The wall-sit test measures the lower-body muscular endurance [29]. In the Wall-sit test, the performer starts with the back against the wall, the legs bent to 90°, and has to hold this sitting-like position for as long as possible. The time for which a performer can hold the position is recorded.

2.3.2. Flexibility

YMCA sit-and-reach test (S&R): The S&R measures the upper chain flexibility [30]. It is related to hamstring flexibility [31]. The performer has to flex the trunk from a seated position, trying to reach (with the fingertips) the farthest point on a measuring box, where the soles of the feet are located. The distance between the middle fingers and the point corresponding to the soles of the feet is measured.

2.3.3. Cardiorespiratory Fitness

Yo-yo IR Level 1 test (YY): The Yo-yo Intermittent Recovery Level 1 test was used to evaluate cardiorespiratory fitness [32]. The performer has to run 40 m (20 m forth and 20 m back) at increasing speeds, set by an acoustic pacer. Ten seconds of rest are observed between each shuttle-run. The test ends either when the performer can no longer follow the pacer (as she does not reach the 40 m line at the signal for two consecutive times), or at the performer's volitional exhaustion.

2.4. Measurements (Submaximal Tests)

Five submaximal tests were selected to evaluate the flexibility, muscular strength and, cardiorespiratory fitness of the participants, and were considered as corresponding to the aforementioned maximal tests.

2.4.1. Muscular Endurance

The submaximal tests to evaluate the muscular endurance replicate the same procedures of the previously described maximal tests, except for the criteria of the interruption of the tests. The performer stops the exercise based on her rate of perceived exertion (RPE), measured by the Borg CR-10 scale: The submaximal push-up test (S-PU), submaximal crunch test (S-CR), and submaximal wall-sit test (S-WS) end when the level of RPE corresponding to the "strong" anchor (i.e., a value of 5 AU) is perceived.

2.4.2. Flexibility

The submaximal bending forward of the trunk test (S-BF): S-BF was selected to be compared to the maximal S&R test. The performer, standing on a measuring box, has to bend the trunk forward with the arms extended. As in S&R, the flexibility is collected by measuring the distance reached by the middle fingers with respect to the soles of the feet. Differently from S&R, the performer does not bend at the maximum, but she has to stop when an internal load of 100 AU on a Stretch Intensity Scale (SIS) is perceived, as described by Freitas et al. [33].

2.4.3. Cardiorespiratory Fitness

Submaximal step test (S-ST): The Margaria step test [34] was used to evaluate the cardiorespiratory fitness instead of the YY maximal test. In the S-ST, the performer has to step up and down on a step with a height of 40 cm at a pace of 54 bpm. As in the other submaximal tests, the performer has to stop when she perceives a level 5 on the Borg CR-10 scale.

We also recorded the heart rate with a 5 s sample heart rate monitor (Polar S810, Polar Electro, Kempele, Finland).

2.5. Statistical Analysis

All statistical procedures were performed using SPSS (version 20.0 Chicago, IL, USA). The normal distribution was verified for each set of data using the Kolmogorov–Smirnov test. The reliability of submaximal tests was assessed using an Interclass Correlation Coefficient (ICC) [35]. The lowest ICC value considered in this study was $r = 0.8$ [36]. The criterion-related validity was assessed via correlation between the average results of each submaximal test with those of the corresponding maximal test. Pearson's Correlation was performed with normally distributed data, while Spearman's Correlation was used when this condition was violated. Alpha was set at 0.05 and a $r > 0.7$ was considered as an acceptable correlation [36]. The R squared values and powers (1-beta) of each main correlation were indicated. Delta values (as percentages) between the maximal/submaximal External Load and the maximal/submaximal Internal Load were calculated.

3. Results

3.1. Reliability of the Submaximal Tests

All of the submaximal tests of muscular endurance and flexibility were found to be reliable, with an ICC that generally showed an $r > 0.8$. In detail, the reliability of S-PU, S-CR, S-WS and S-ST was r = 0.965, r = 0.894, r = 0.819 and r = 0.942, respectively. S-BF had the higher value of reliability (r = 0.974).

3.2. Criterion Validity of the Submaximal Tests

The criterion validity of the submaximal tests is supported by the correlation analysis between the maximal and submaximal test outputs. Significant correlations were found between all of them except between YY and S-ST, between which the correlation was $r = 0.380$, $p > 0.05$ (Figure 2e).

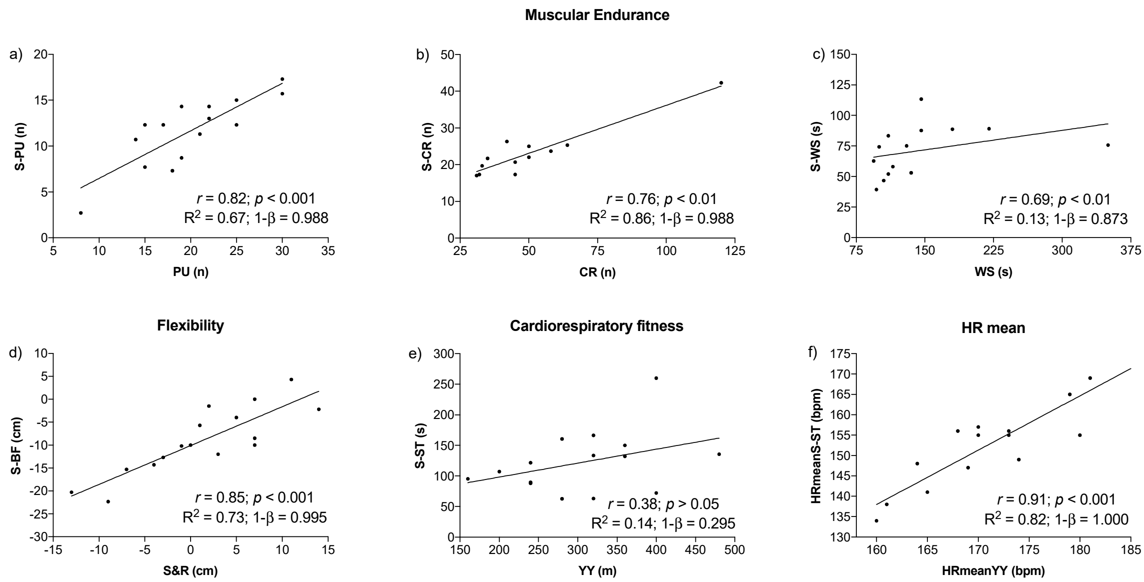

Figure 2. Correlations between maximal and submaximal tests. Panels (**a**–**c**) refer to the muscular endurance (upper limbs, abdominal muscles, and lower limbs, respectively); panel (**d**) refers to the flexibility; panels (**e**) and (**f**) refer to the cardiorespiratory fitness (maximal vs. submaximal performance and HR_{mean} from the start to stop the test, respectively).

As Figure 2 shows, the muscular endurance of the upper limbs and of the abdominal muscles resulted in a high correlation: $r = 0.821$ ($p < 0.001$) between S-PU and PU (Figure 2a) and rho = 0.764 ($p < 0.01$) between S-CR and CR (Figure 2b), respectively. S-WS, meanwhile, was not highly correlated with WS (rho = 0.694, $p < 0.01$; Figure 2c).

With respect to the flexibility, a strong correlation (r = 0.852, $p < 0.05$) was found between S&R and S-BF (Figure 2a).

For cardiorespiratory fitness, even if YY and S-ST were not related, the analysis of the mean heart rates (YY HR_{mean} and S-ST HR_{mean}) recorded during the test execution unveiled a significant correlation between the maximal and the submaximal procedures ($r = 0.907$, $p < 0.001$; Figure 2f).

3.3. Delta Values Between Maximal and Submaximal Tests

The percentage differences between the results of the maximal and submaximal tests (i.e., External load, EL) were further related to the percentage differences with respect to the RPEs that were surveyed during the trials (i.e., Internal load, IL) or to the SIS in the case of S&R and S-BF flexibility tests. Therefore, EL refers to the delta between the measures of maximal and submaximal tests, whereas IL refers to the delta between the perceived exertion during the gold-standard measures (maximal tests, RPE = 10 or SIS = 150) and submaximal tests (RPE = 5 and SIS = 100), which means that the closer the value is to 50% (RPE) and 75% (SIS), the more properly the submaximal test was performed. Data and comparisons are reported in the Tables 2 and 3.

Table 2. Results of the testing procedures.

	Max	Submax	Mean Diff.	Sig.	95% CI Lower Bound	95% CI Upper Bound	Submax Compa-Red to Max (%)
Muscular endurance							
Push-up (nr)	20.0 ± 6.0	11.7 ± 3.8	8.3 ± 3.6	<0.001	4.587	12.093	58
Crunch (nr)	50.4 ± 24.3	23.2 ± 6.8	27.2 ± 18.1	<0.001	12.141	42.310	46
Wall-sit (s)	145.6 ± 68.5	71.3 ± 20.4	74.2 ± 64.2	<0.001	33.560	114.911	49
Flexibility							
Sit & reach (cm)	1.25 ± 7.3	−9.0 ± 7.3	10.3 ± 3.9	<0.001	5.024	15.564	68
Cardiorespiratory fitness							
HR_{mean} (bpm)	170.7 ± 8.5	151.8 ± 13.0	18.9 ± 5.9	<0.001	10.871	26.754	89

Data are reported as mean ± SD. The last column shows the submaximal values as percentages in comparison to the corresponding maximal values, which are considered as references (i.e., =100% of the effort). Mean heart rate (HR_{mean}) was measured during the Yo-yo Intermittent Recovery (IR) test (maximal) and the Margaria step test (submaximal).

Table 3. Perceived exertion in the testing procedure (rate of perceived exertion (RPE) for muscular endurance and cardiorespiratory fitness and Stretch Intensity Scale (SIS) for flexibility).

	Max	Sub-max	Mean Diff.	Sig.	95% CI Lower Bound	95% CI Upper Bound	Submax Compa-Red to Max (%)
Muscular endurance							
Push-up (nr)	9 ± 1	5	4.4 ± 1.0	<0.001	3.888	4.987	53
Crunch (nr)	9 ± 3	5	3.9 ± 1.1	<0.001	3.353	4.504	61
Wall-sit (s)	10 ± 1	5	4.8 ± 0.8	<0.001	4.368	5.257	51
Flexibility							
Sit & reach (cm)	134 ± 6	100	34.2 ± 6.4	<0.001	30.360	38.101	74
Cardiorespiratory fitness							
Yo-yo and step test (AU)	10 ± 1	5	4.6 ± 1.0	<0.001	4.080	3.171	52

Data are reported as mean ± SD. The submaximal column has no SD and corresponds to 5 (Borg CR-10) or 100 (SIS), as participants stopped the test at this value of perceived exertion. The last column shows the percentage of the submaximal perceived exertion compared to that perceived in the maximal tests.

4. Discussion

This study compared some maximal and submaximal tests to evaluate muscular endurance, flexibility, and cardiorespiratory fitness in active young adult female participants, and showed that submaximal tests, based on an IL at about 50% of the RPE scale and about 75% of the SIS scale, are equally valid and reliable to the corresponding gold-standard maximal tests. Therefore, they can be more safely and easily administered, confirming the criterion-related validity. The only exception is represented by the cardiorespiratory evaluation.

The correlation values (r = 0.821 and rho = 0.785, respectively) of S-PU and S-CR can also be considered acceptable [36] and valid for assessing the muscular endurance; this is not in agreement with the study by Crotti et al. [23], in which crunch and push-up tests showed a weak correlation with respect to the maximal tests. In addition, even if marginally, S-WS also had significant values of correlation with WS. Altogether, we can support the evidence that the selected submaximal tests are suitable for replacing the somehow harmful maximal tests for evaluating muscular endurance.

In agreement with the previous study [23], S-BF showed a very high correlation with its S&R maximal counterpart (r = 0.852), even higher than those of the submaximal tests considered by these authors, and can be considered reliable for measuring flexibility. Indeed, further studies have used S&R as a gold standard to validate the sit-and-reach-with-back-saver test [30].

With regards to the cardiorespiratory fitness, there is no correlation between YY and S-ST, which is between an effort at the maximal RPE and a submaximal test at a level 5 of the CR-10 RPE scale. When HR is considered, the high values recorded during S-ST can be explained by the early accumulation of plasmatic lactate [37]. In fact, according Zamuner et al. [38], during incremental tests, the level 5 of RPE is related to the anaerobic threshold. Moreover, Simon et al. [37] highlighted that untrained people can reach the lactate threshold before the ventilation threshold, and this supports the high HR reported in S-ST [39]. It is noteworthy that, compared to the study of Crotti et al. [23] that considered a sample of experienced male runners, the participants in our follow-up study differed in gender (females) and training experience, as the IPAQ reported the status of physical activity of our sample as "moderate". This category is defined as "doing some activity, more than the low-activity category". This level of activity is equivalent to "half an hour of at least moderate-intensity physical activity on most days" [24].

The internal load of S-PU, S-CR, and S-WS was set at a level 5 (hard) of the CR-10 scale, i.e., at 50% of the scale. It is interesting to observe that this internal load (that served to stop the testing procedure) corresponded to about the 50% of the external load, as measured by the maximal tests (Table 2).

This brings an interesting reflection: A training study by Gine-Garriga et al. [40] used the level 12–14 (somewhat hard) of Borg RPE 6–20 to determine the number of repetitions for training older adults for lower body workloads. This method achieved an enhancement of strength for lower limbs and, during the training period, their repetitions at the same perceived effort rose [40]. Using the same rationale, a range of 51%–61% of the internal load (hard) can be used to determine a number of repetitions that corresponds to a range of 46%–58% of the maximal repetitions. The level 5 (hard) of CR-10 for S-PU, S-CR, and S-WS can be a useful tool for assessing the maximal number of repetitions when planning a training routine.

4.1. Limitations of the Study

One limitation of the study is represented by the low sample size: A greater number of participants might have allowed a more accurate evaluation of the phenomenon and, possibly, more detailed information about the cardiorespiratory fitness assessment. In addition, male practitioners should be considered in order to confirm the validity and reliability of the submaximal tests regardless of gender.

4.2. Sustainability of the Educational Rationale of Physical Activity

Sustainability includes the concept of an individual's responsibility towards her/his health and welfare. A physical activity that respects the characteristics of the individual represents the best investment aimed to reduce the population health costs. In other words, reinforcing the people's capacity to act with awareness for monitoring their own health status and then improving their wellness is paramount to developing knowledge, competence, and the belief that it is useful to practice regular physical exercise. Learning how to monitor one's own level of physical efficiency by means of perceived exertion represents a competence that is useful in facing known or new situations. Submaximal tests, based on the perceived exertion, can be considered educative tools. They are objective in nature (that is, in terms of quantification of the number of repetitions, distance covered, time elapsed, etc.) but are characterized by a subjective implication that determines the self-consciousness of an individual. Behaving in this direction (educational rationale of physical activity) encourages the calibration mechanisms of self-acting that are useful for promoting health and a proper use of the body, but not its overuse. The background of the educational rationale is self-awareness, which can be defined as an autonomous and responsible behavior aimed at understanding and trusting their own capacities and limits, and having a realistic image of themselves.

5. Conclusions

In conclusion, relying on the scientific literature validation criteria and on the results obtained in the present study, we can assert that muscular endurance and submaximal flexibility tests meet all of the necessary criterion-related conditions to be considered as valid and reliable as the maximal gold-standard landmarks. We cannot infer the same conclusion for the S-ST submaximal test to evaluate cardiorespiratory fitness, probably because different motor patterns were involved in these two exercises.

Since the moderately active female population is not accustomed to maximal tests, these might not be feasible in that population. As our study showed, the use of submaximal tests using RPE and SIS scales as references to manage the effort during the testing procedure can properly replace the usual maximal testing procedures in non-competitive athletes. We are therefore confident that this study might offer an important contribution to the process of the evaluation of fitness status in not-highly trained people by avoiding the constraints represented by the maximal efforts that are required to properly complete measurements with the usual gold-standard tests. This might help physical education teachers and trainers to evaluate untrained people, as well as to reduce injury risks and promote adherence to physical exercise. This approach makes possible the transition from a "drug-like" to an "educational" rationale, where the "body–mind" is overcome.

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